

Allelic Frequency of Kappa-Casein Locus (Asp148/Ala) in F₁: Simmental (*Bos taurus*) x Ongole Grade (*Bos indicus*)

M. A. Mu'in* & A. Supriyantono

Faculty of Animal Science, Fishery and Marine Science,
Papua State University, Manokwari, West Papua
Jln. Gunung Salju, Amban, Manokwari 98314, Indonesia
(Received 09-05-2012; Reviewed 23-07-2012; Accepted 04-09-2012)

ABSTRACT

This study was conducted to detect the genetic variants (single nucleotide polymorphism) of kappa-casein locus (Asp148/Ala) in F₁: Simmental (*Bos taurus*) x Ongole grade (*Bos indicus*), SIMPO. Genomic DNA was isolated from blood sample of 40 SIMPO (21 males and 19 females). A 780 bp specific fragment of kappa-casein gene spanning from the forth exon region (517 bp) to forth intron (263 bp) was successfully amplified. The result of the PCR-RFLP (Polymerase Chain Reaction – Restriction Fragment Length Polymorphisms) analysis using *HindIII* enzyme showed that two genotypes (AA and AB) were found at this locus in SIMPO. The frequencies of A and B alleles in SIMPO were 0.79 and 0.21, respectively. The frequency lies between *B. taurus* (Simmental) and *B. indicus* group.

Key words: gene, locus, kappa-casein, PCR-RFLP, SIMPO

ABSTRAK

Penelitian ini bertujuan untuk mendeteksi varian (polimorfisme nukleotida tunggal) pada lokus kappa-casein (Asp148/Ala) pada F₁: Simmental (*Bos taurus*) x Peranakan Ongole (*Bos indicus*), SIMPO. DNA genom yang digunakan diisolasi dari 40 sampel darah sapi SIMPO (21 jantan dan 19 betina). Fragmen DNA spesifik dari gen kappa-casein yang merentang dari daerah exon-IV (517 bp) hingga daerah intron-IV (263 bp) telah berhasil diamplifikasi. Hasil analisis PCR-RFLP (polymerase chain reaction – restriction fragment length polymorphisms) menggunakan enzim *HindIII* ditemukan dua genotip (AA and AB) pada lokus tersebut pada sapi SIMPO. Frekuensi alel A dan B lokus ini pada SIMPO berturut-turut 0,79 dan 0,21. Frekuensi alel ini berada diantara *B. taurus* (Simmental) dan *B. indicus*.

Kata kunci: gen, kappa-casein, PCR-RFLP, SIMPO

INTRODUCTION

Recently in some areas of Indonesia, many cross breeding between superior bulls of Simmental (*Bos taurus*) and Ongole grade (*Bos indicus*) have been done. The Simmental cattle originated from Switzerland, they belong to dual-purpose type (beef and milk type) (Simmental Australia, 2012), and body weight of bulls and cows are about 1,000 kg (BBIB Singosari, 2012) and 605.7±51.8 kg (Pilarczyk & Wojcik, 2008), respectively. The Ongole grade (in Indonesia: *Peranakan Ongole*, PO) was the result of *grading up* between Java cattle and Ongole, and body weight of bulls and cows are about 315.6±39.46 kg (Carvalho *et al.*, 2010) and 295±59.82 kg (Endrawati *et al.*, 2010), respectively. The Ongole cattle

breed, also known as *Nellore* cattle breed, came from Madras, India, they belong to dual-purpose type (beef and work type) (Gaur *et al.*, 2002). The result of crossing between superior bulls of Simmental (*B. taurus*) and Ongole grade (*B. indicus*) called as SIMPO (abbreviation: Simmental and PO). The cross breed of beef cattle are expected to be more rapid in growth as well more productive as a meat producer.

The pre-weaning growth of cattle highly correlated to post-weaning growth. The pre-weaning growth itself depends on milk intake from the dam. The dam which had good milk performance will have maternal ability as well. Calves which born from the dam like that will get a chance to consume a good milk so the pre-weaning growth would be better as well.

Kappa-casein is one of the milk proteins that are essential for pre-weaning growth. Kappa-casein of cow consisted of 169 amino acids (Martin *et al.*, 2002). Production of kappa-casein of cows was controlled

*Corresponding author:
E-mail: muinunipa@gmail.com

by a gene located on chromosome 6, approximately 13 kb in size and was divided into 5 exons and 4 intron (Alexander *et al.*, 1988; Rohallah *et al.*, 2007). Exon 1 codes for 65 nucleotides of the 5'-untranslated region, exon 2 contains the remaining 5 nucleotides of the 5'-untranslated region and codes for 19 of the 21 amino acids of the leader peptide. Exon 3 contains only 33 nucleotides while exon 4 codes for the remainder of the mature protein as well as 37 nucleotides of the 3'-untranslated region, the remaining 173 nucleotides of which are contained in exon 5. Intron 1-4 are 2.5 kb, 5.8 kb, 2.0 kb and 1.8 kb in length respectively (Alexander *et al.*, 1988). Along the gene it was found some genetic variants (Hamza *et al.*, 2010).

By PCR-RFLP analysis using *HindIII* or *HinfI* enzyme, some researchers have found a point mutation in exon 4 of kappa-casein gene in some breeds of cattle, and generally the locus is found two variant alleles: A and B. A and B alleles found in *B. taurus* and *Bos indicus*. The frequency of B allele of *B. taurus* is relatively higher than of *B. indicus*, but in *Bos sondaicus* was solely found B allele (Table 2). The sequencing of amino acid (nucleotides) showed that the B allele was found alanine (GCT) at position 148 of the amino acid sequence, while the A allele positions are occupied by aspartic acid (GAT) (Figure 3) (Alexander *et al.*, 1988; Strzalkowska *et al.*, 2002; Patel *et al.*, 2007). Anggraeni *et al.* (2010) detected B allele of kappa-casein for Holstein-Friesian by PCR-RFLP analysis using *PstI* enzyme, and they found B allele frequency of farm in west Java (Indonesia) which manage semi-intensive and intensively was 0.36 and 0.37, respectively. However, B allele frequency of two national AI station in Indonesia (BIB Lembang and BIB Singosari) was 0.26 and 0.45, respectively.

The presence of B allele of kappa-casein locus (Asp148/Ala) has given a positive effect on milk production and milk protein content in Holstein cows (Tsiaras *et al.*, 2005). Alipanah *et al.* (2008) reported that in the two breed of Russian cattle -Russian Black Pied and Russian Red Pied, BB genotype had a milk protein content was higher than AA and AB genotype. Another study had reported that the BB genotype in Sahiwal (*B. indicus*) was able to produce milk monthly and 305 days, and protein monthly was higher than AA and AB genotypes (Rachagani & Gupta, 2008). Anggraeni *et al.* (2009) reported that high milk protein was affected by BB genotype of the kappa-casein gene (i.e. point mutation in exon 4 detected by PCR-RFLP/*PstI*) in Holstein-Friesian female herd of West Java Province (Indonesia). The result suggested that it would be a good opportunity to be used as MAS (Marker Assisted Selection) in Holstein-Friesian domestic.

In the view of beef cattle, information concerning polymorphism effect of kappa-casein on growth performance was very rare. Lara *et al.* (2002) stated that variation of kappa-casein plays important role on growth and maternal effect of beef cattle breeds. Curi *et al.* (2005) found the same phenomenon such as dairy cattle, where frequency of A allele of kappa-casein was higher than B allele at beef cattle breeds (Nellore, Canchim, Simmental x Nellore, dan Angus x Nellore).

The study aimed to determine the allelic frequency of kappa-casein locus (Asp148/Ala) in SIMPO population by PCR-RFLP analysis using *HindIII* enzyme. The result of study will be the basis of efforts to improve the effectiveness and efficiency of crossing in order to generate new productive beef cattle breed as meat producers.

MATERIALS AND METHODS

The material used in the study were genomic DNA isolated from blood samples of 40 SIMPO, consisted of 21 males and 19 females (Mu'in *et al.*, 2007). The SIMPO were owned by the farmers in Bantul Regency, Yogyakarta Province, Indonesia. Figure 1 shows some SIMPO and the dam. The study was conducted at the Laboratory of Biochemistry, Biotechnology Study Center, University of Gadjah Mada.

Amplification of specific DNA fragment (780 bp) that spans from the 4th exon (517 bp) to the 4th intron (263 bp) of kappa-casein gene, carried out using pair of primers [M1, (forward), 5'-CGCTGTGAGAAAGATGAAAGATTTC-3'; M2 (reverse), 5'-AGATTCAAG GAGTATACCAATTGTTG-3', (Chikuni *et al.*, 1991)]. Amplification procedure was as follows: a 2 µL solution of genomic DNA (± 100 ng), pair of primers (M1 and M2, each 2 µL, 16 pmol concentration), and 19 µL dH₂O inserted into a tube of 0.2 mL Ready-To-Go PCR Bead (Amersham Biosciences). PCR conditions was programmed as follows: initial denaturation 95 °C for 2 min, followed by amplification of 35 cycles with each cycle program: denaturation 94 °C for 1 min, annealing 55 °C for 1 min, extension 72 °C for 1 min. The final stage was an extra extension at 72 °C for 5 min.

PCR products obtained was digested by restriction enzyme *HindIII*. The procedure was as follows: 10 µL PCR product, 8 µL dH₂O and 2 µL restriction enzyme (*HindIII*) was put into 1.5 mL microtube, then incubated overnight at 37 °C. Digestion products were electrophoresed on 1.5% agarose gel containing Nucleic Acid Stain GoldView in TBE buffer. The TBE buffer was a mixture containing 108 g Tris base and 55 g boric acid in 700 mL aquabides, then added by 40 mL 0.5 M EDTA (pH 8,0), and added by aquabides in solution up to 1L of total volume. DNA marker (DirectLoad™ Wide Range DNA Marker, Sigma production) and one of the PCR products were included in the same gel to help the process of identification. Running of the gel was performed at a voltage 100 volts for 30 min. The results of electrophoresis were examined under ultraviolet light, then photographed. Identification of alleles and genotypes of kappa-casein locus was done by comparing band pattern of each sample to the DNA marker bands according to Chikuni *et al.* (1991).

Allele frequency of kappa-casein locus was calculated using the formula (Nei & Kumar, 2000):

$$X_i = (2n_{ii} + \sum n_{ij}) / (2n)$$

where: X_i = allele frequency of the i-th

n_{ii} = number of ii genotypes

n_{ij} = number of ij genotypes

n = number of samples



Figure 1. SIMPO and the dam (Ongole grade). Patterns and colors of calves skin of SIMPO are vary: the upper-left (grey and white striped body), upper right (brown and white stripes on the body), bottom left (brown without stripes, white in the foot), bottom right (dark brown without stripes).

RESULTS AND DISCUSSION

Specific DNA fragment, size 780 bp which extending from the 4th exon (517 bp) to the 4th intron (263 bp) of kappa-casein gene, containing the polymorphic region

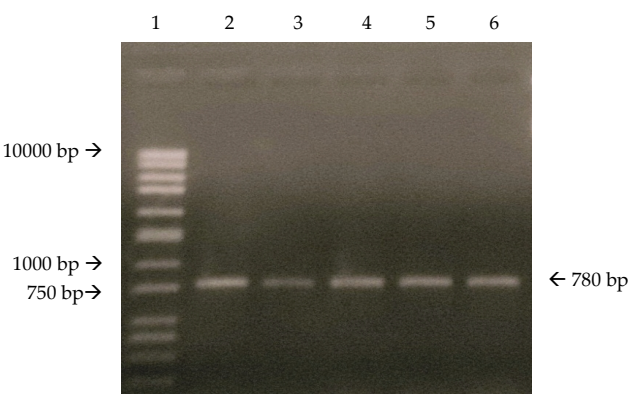


Figure 2. PCR products of SIMPO analysed in a 1,5% agarose gel containing Nucleic Acid Stain GoldView[Lane 1 = DNA markers, lanes 2-6 = PCR product (780 bp)].

(Chikuni *et al.*, 1991), were successfully amplified from 40 genomic DNA ofSIMPO [herd of first crossing (F₁) between Simmental and Ongole grade] using M1 and M2the primers (Figure 2). Figure 3 shows the nucleotide sequence of a specific DNA fragment (780 bp) of kappa-casein gene (Alexander *et al.*, 1988; Genbank No.378700), and cutting sites of *Hind*IIIenzyme (A↓AGCTT).

Digestion of amplicon (PCR product) on all samples using *Hind*III produced two genotypes: AA (indicated

Exon-4→														
Primer forward (M1)→														
1	..5'	CGC	TGT	GAG	AAA	GAT	GAA	AGA	TTC	TTC	AGT	GAC	AAA	ATA
40	GCC	AAA	TAT	ATC	CCA	ATT	CAG	TAT	GTG	CTG	AGT	AGG	TAT	CCT
82	AGT	TAT	GGA	CTC	AAT	TAC	TAC	CAA	CAG	AAA	CCA	GTT	GCA	CTA
124	ATT	AAT	AAT	CAA	TTT	CTG	CCA	TAC	CCA	TAT	TAT	GCA	AAG	CCA
166	GCT	GCA	GTT	AGG	TCA	CCT	GCC	CAA	ATT	CTT	CAA	TGG	CAA	GTT
208	TTG	TCA	AAT	ACT	GTG	CCT	GCC	AAG	TCC	TGC	CAA	GCC	CAG	CCA
250	ACT	ACC	ATG	GCA	CGT	CAC	CCA	CAC	CCA	CAT	TTA	TCA	TTT	ATG
292	GCC	ATT	CCA	CCA	AAG	AAA	AAT	CAG	GAT	AAA	ACA	GAA	ATC	CCT
334	ACC	ATC	AAT	ACC	ATT	GCT	AGT	GGT	GAG	CCT	ACA	AGT	ACA	CCT
HindIII														
376	ACC	ACC	GAA	GCA	GTA	GAG	AGC	ACT	GTA	GCT	ACT	CTA	GAA	GCT
	Thr	Thr	Glu	Ala	Val	Glu	Ser	Thr	Val	Ala	Thr	Leu	Glu	Ala
	135	136	137	138	139	140	141	142	143	144	145	146	147	148
↓														
B-allele														
or														
GAT														
Asp														
148														
↓														
A-allele														
418	TCT	CCA	GAA	GTT	ATT	GAG	AGC	CCA	CCT	GAG	ATC	AAC	ACA	GTC
	Ser	Pro	Glu	Val	Ile	Glu	Ser	Pro	Pro	Glu	Ile	Asn	Thr	Val
	149	150	151	152	153	154	155	156	157	158	159	160	161	162
460	CAA	GTT	ACT	TCA	ACT	GCA	GTC	TAA	AAACTCTA	AGGAGACATCAA	AGAAGA			
	Gln	Val	Thr	Ser	Thr	Ala	Val	Stop						
	163	164	165	166	167	168	169							
Intron 4→														
510	CAACGCAG--GTAATAAGGCCAAATGAATAACAGGCCAAGATTCATGGACTTATTAATAAAAT													
572	CGTAACATCTAAACTAGCGTAGATGGATAAAATTAATCTGTTACAGAGAAGGCGAAATGGCTAA													
636	TTATAACTTACATTTGCTGGTCTTTATCATGTATATACTAGATTCTTTGCCAACAAGAAAGTT													
700	TTAAAATATTTTACAAAATGAGTAAAAATGCAGATTTTATTATTAAACCTTTTTCAACAATTG													
764	GTATACTCCTTGAATCT--..3'													
← Primer reverse (M2)														

Figure 3. The sequence of DNA fragment of kappa-casein gene bovine (PCR product, size: 780 bp) extending from the 4th exon (517 bp) to the 4thintron (263 bp), and their some of amino acid sequences (source: Alexander *et al.*, 1988; Genbank No.378700), and *Hind*III enzyme cut sitesat nucleotide position 414 (A↓AGCTT).

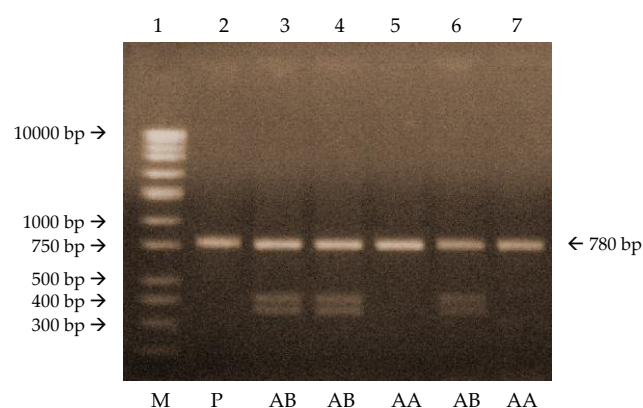


Figure 4. The PCR-RFLP electrophoresis products of kappa-casein locus (Asp148/Ala) in SIMPO using *Hind*III enzyme [Lane 1=M (DNA markers), lane 2=PCR product (780 bp), lanes 3, 4, and 6=AB genotype (780 bp, 413 bp, 367 bp), lanes 5 and 7=AA genotype (780 bp)]

by the presence of one band: 780 bp) and AB (three bands: 780 bp, 413 bp and 367 bp). BB genotype which is characterized by two bands: 413 bp and 367 bp (Chikuni *et al.*, 1991) was not found in the study. Band pattern which characterizes a genotype that found in this study

is the same as was found by Chikuni *et al.* (1991). Figure 4 shows the genotype of kappa-casein locus (Asp148/Ala) in SIMPO of the study.

Based on the genotype found of the study, it was known that the kappa-casein locus consisted A allele (a DNA fragment sized 780 bp) and B allele (two DNA fragments sized 413 bp and 367 bp). B allele of kappa-casein locus was demonstrated by the success of the *Hind*III (5'.. A ↓ AGCTT .. 3') found DNA sequences that were recognized throughout the PCR products and success to cut them into two fragments sized 413 bp and 367 bp. Referring to the DNA sequences available on GenBank No. EF378700 and amino acid sequencing results reported by Alexander *et al.* (1988), it could be explained that the success of *Hind*III to find a sequence was due to the-416 nucleotide sequence (Figure 3) occupied by C (cytosine), so the sequence of triplet codons are GCT which encode alanine (Ala) at position 148 of the polypeptide chain of kappa-casein. In contrast, the A allele is indicated by the failure of *Hind*III find a recognizable DNA sequences along the PCR products. As a result the size of the PCR products before and after digested remain the same, which is 780 bp. The *Hind*III (5'.. A ↓ AGCTT .. 3') failed to find DNA sequences that were recognized due to the-416 nucleotide sequence (Figure 3) occupied by A (adenine), so the sequence of

Table 1. The frequency of A and B alleles of kappa-casein locus (Asp148/Ala) in SIMPO (*Bos taurus* x *Bos indicus*) and some breeds of *B. taurus*, *B. indicus*, and *B. taurus* x *B. indicus*

Group	Breed	n	Frequency of kappa-casein allele*)		Source
			A	B	
<i>Bos sondaicus</i>	Bali	60	0.00	1.00	Mu'in & Supriyantono, 2012
<i>Bos taurus</i>	Brown Swiss	93	0.49	0.51	Dogru & Ozdemir, 2009
	Holstein	224	0.59	0.41	Doosti <i>et al.</i> , 2001
	Russian Red Pied	52	0.65	0.35	Alipanah <i>et al.</i> , 2008
	Simmental	80	0.69	0.31	Vasconcellos <i>et al.</i> , 2003
	Sarabi	66	0.76	0.24	Toorchi <i>et al.</i> , 2006
	Iranian Native	210	0.81	0.19	Doosti <i>et al.</i> , 2011
	Russian Black Pied	72	0.83	0.17	Alipanah <i>et al.</i> , 2008
	Holstein-Friesian (HF)	304	0.83	0.17	Sitkowska <i>et al.</i> , 2008
	Tharparkar	52	0.86	0.14	Rachagani & Gupta, 2008
<i>Bos indicus</i>	Sahiwal	252	0.87	0.13	Rachagani & Gupta, 2008
	Nellore	79	0.89	0.11	Curi <i>et al.</i> , 2005
	Guzerat	25	0.92	0.08	Kemenes <i>et al.</i> , 1999
	Gyr	746	0.93	0.07	Azevedo <i>et al.</i> , 2008
	Jersey x Zebu	112	0.52	0.48	Patel <i>et al.</i> , 2007
<i>Bos taurus</i> x <i>Bos indicus</i>	HF x Zebu	256	0.72	0.28	Patel <i>et al.</i> , 2007
	Canchim (5/8 Charolais x 3/8 Zebu)	30	0.77	0.23	Curi <i>et al.</i> , 2005
	Angus x Nellore	245	0.78	0.22	Curi <i>et al.</i> , 2005
	SIMPO	40	0.79	0.21	In this study
	Simmental x Nellore	30	0.80	0.20	Curi <i>et al.</i> , 2005

Note: *) Single Nucleotide Polymorphism in exon 4 region in kappa-casein gene [Asp 148 (GAT, A allele)/Ala (GCT, B allele)].

triplet codons formed was GAT that encode amino acid aspartate (Asp) at position 148 of the polypeptide chain of kappa-casein.

Genotype frequencies of AA, AB and BB genotype were 57.5%, 42.5%, and 0%, respectively. So, the frequencies of A and B alleles at this locus were 0.79 and 0.21, respectively. The results of this study indicate that locus of the kappa-casein (Asp148/Ala) on the SIMPO was polymorphic, because allele frequencies which commonly found in the population (A allele), does not exceed 0.99 (Nei & Kumar, 2000). The distribution of genotypes of kappa-casein locus which found in SIMPO indicated that there were flow (migration) of B allele. Migration of B allele might come from the sire, Simmental (*B. taurus*), because in general the Simmental cattles which belonging to *B. taurus* are abundant in B allele compare to *B. indicus*.

Table 1 presents the frequency of A and B alleles of the kappa-casein locus of SIMPO (*B. taurus* x *B. indicus*) which found in the study. As comparison it was also shown A and B allele frequency of kappa-casein locus (Asp148/Ala) on some other breed (*B. taurus*, *B. indicus*, and *B. taurus* x *B. indicus*). Based on Table 1 it was known that the breeds of *B. taurus* generally had a higher frequency of B alleles than the breeds of *B. indicus*, while SIMPO which the result of crossing of *B. taurus* (Simmental) x *B. indicus* (Ongole grade) has the B allele frequency higher than the breeds of *B. indicus*, particularly when it was compared to Nellore breed (*B. indicus*) which was as ancestors to breed Ongole grade.

Based on the frequency of alleles of the kappa-casein it can be said that the frequency of B allele of SIMPO laid between *B. taurus* and *B. indicus*. Thus, cross breeds between Simmental and Ongole grade was able to increase the frequency of B allele in a population of progeny (SIMPO). Increasing frequency of B allele of SIMPO might have come from Simmental (*B. taurus*). Tabel 1 showed that some breeds of crossing between *B. taurus* and *B. indicus* had higher B allele frequency than those of parents of *B. indicus*. It was strongly evident that the crossing between *B. taurus* and *B. indicus* was able to increase of B allele frequency of the crossing breed.

Most reports suggest that the increased frequency of B allele of kappa-casein locus had a positive effect on performance and quality of milk production on some breeds of cattle (Alipanah *et al.*, 2008; Rachagani & Gupta, 2008). This phenomenon might also apply to the SIMPO breed, where increasing of B allele frequency in SIMPO population would have positive effect on milk performance of SIMPO dams. The increasing of the milk performance would be positive effect on pre-weaning growth of calves in the next generation. The calves born will get a chance to consume good milk so the pre-weaning growth would be better. When the phenomenon is true, then the frequency of B allele should be increased in population by increasing the frequency of BB or AB genotype in SIMPO populations. The use of BB or AB genotypes of Simmental as bulls will be very effective in order to increase the frequency of B allele in the SIMPO population. Of this method crossbreeding in the framework of SIMPO breed will become more directional as

expected to create a new productive breed of beef cattle as meat producers.

CONCLUSION

The SIMPO (*B. taurus* x *B. indicus*) had a frequency of B allele (0.21) was lower than A allele (0.79). However, the actual frequency of B allele was quite moderate, as occupying a higher position than that commonly found in *B. indicus*.

REFERENCES

- Alexander, L., A. F. Stewart, A. G. Mackinlay, T. V. Kapelinskaya, T. N. Tkach, & S. I. Gorodetsky. 1988. Isolation and characterization of the bovine κ -casein gene. *Eur. J. Biochem.* 178: 395-401. <http://dx.doi.org/10.1111/j.1432-1033.1988.tb14463.x>
- Anggraeni, A., C. Sumantri, A. Farajallah, & E. Andreas. 2009. Verifikasi kontrol gen kappa kasein pada protein susu sapi Friesian-Holstein di daerah sentra produksi susu Jawa Barat. *JITV* 14: 131-141.
- Anggraeni, A., C. Sumantri, A. Farajallah, & E. Andreas. 2010. Kappa-casein genotype frequencies in Holstein-Friesian dairy cattle in West Java province. *Med. Pet.* 33: 61-67. <http://dx.doi.org/10.5398/medpet.2010.33.2.61>
- Alipanah, M., L. A. Kalashnikova, & G.V. Rodionov. 2008. Kappa-casein and PRL-RSA I genotypic frequencies in two Russian cattle breeds. *Arch. Zootec.* 57: 131-138.
- Azevedo, A. L. S., C. S. Nascimento, R. S. Steinberg, M. R. S. Carvalho, M. G. C. D. Peixoto, R. L. Teodoro, R. S. Verneque, S. E. F. Guimaraes, & M. A. Machado. 2008. Genetic polymorphism of the kappa-casein gene in Brazilian cattle. *Genetica and Molecular Research* 7: 623-630. <http://dx.doi.org/10.4238/vol7-3gmr428>
- BBIB (Balai Besar Inseminasi Buatan) Singosari. 2012. Katalog-Simental. www.BBIBSingosari.com/variant [10 December 2012].
- Carvalho, M. C., Soeparno, & N. Ngadiyono. 2010. Pertumbuhan dan produksi karkas sapi Peranakan Ongole dan Simmental Peranakan Ongole jantan yang dipelihara secara feedlot. *Buletin Peternakan* 34: 38-46.
- Chikuni K., S. Kageyama, T. Koishikawa, S. Kato, & K. Ozutsumi. 1991. Identification of bovine κ -casein genotype using polymerase chain reaction method. *Anim.Sci.Technol. (Jpn)*. 62: 654-659.
- Curi, R. A., H. N. De Oliveira, M. S. Gimenes, A. C. Silveira, & C. R. Lopes. 2005. Effect of CSN3 and LGB gene polymorphism on production traits in beef cattle. *Genet. Mol. Biol.* 28: 262-266. <http://dx.doi.org/10.1590/S1415-47572005000200015>
- Dogru, U. & M. Ozdemir. 2009. Genotyping of kappa-casein locus by PCR-RFLP in Brown Swiss cattle breed. *J. Anim. Vet. Advances* 8: 779-781.
- Doosti, A., A. Arshi, M. Vatankhah, & P. Amjadi. 2011. Kappa-casein gene polymorphism in Holstein and Iranian native cattle by polymerase chain reaction restriction fragment length polymorphism (PCR-RFLP). *Afr. J. Biotech.* 10: 4957-4960.
- Endrawati, E., E. Baliarti, & S. P. S. Budhi. 2010. Performans induk sapi silangan Simmental-Peranakan Ongole dan induk sapi Peranakan Ongole dengan pakan hijauan dan konsentrat. *Buletin Peternakan* 34: 86-93.
- Gaur, G. K., S. N. Kaushik, & R. C. Garg. 2002. Ongole cattle status in India. *Animal Genetic Resources Information* 32: 27-34. <http://dx.doi.org/10.1017/S101423390001528>

- Hamza, A. E., X. L. Wang, & Z. P. Yang. 2010. Kappa casein gene polymorphism in Holstein Chinese cattle. *Pak. Vet. J.* 30:203-206.
- Kemenes, P. A., L. C. A. Reginato, A. J. M. Rosa, I. U. Parker, G. A. Razook, L. A. Figueiredo, N. A. Silva, M. A. L. Etchegaray, & L. L. Coutinho. 1999. κ -casein, β -lactoglobulin and growth hormone allele frequencies and genetic distance in Nelore, Gyr, Guzera, Caracu, Charolais, Canchin and Santa Gertrudis cattle. *Genet. Mol. Biol.* 22: 539-541. <http://dx.doi.org/10.1590/S1415-47571999000400012>
- Lara, M. A. C., L. T. Gama, G. Bufarah, J. R. B. Sereno, E. M. L. Celegato, & U. P. de Abreu. 2002. Genetic polymorphisms at the κ -casein locus in Pantaneiro cattle. *Arch. Zootec.* 51: 99-105.
- Martin, P., M. Szymanowska, L. Zwierzchowski, & C. Leroux. 2002. The impact of genetic polymorphism on the protein composition of ruminant milks. *Reprod. Nutr. Dev.* 42: 433-459. <http://dx.doi.org/10.1051/rnd:2002036>
- Mu'in, M. A., M. Astuti, Muladno, T. W. Murti, & W. T. Artama. 2007. Polimorfisme gen growth hormone dan hubungannya dengan sifat pertumbuhan sapi silangan Peranakan Ongole dan Simmental. *J. Animal Production* 9:53-58.
- Mu'in, M. A. & A. Supriyantono. 2012. Identification of κ -casein polymorphism in Bali cattle. *J. Agricultural Science and Technology A* 2:397-401.
- Nei, M. & D. Kumar. 2000. Molecular evolution and phylogenetics. Oxford University Press, New York.
- Patel, R. K., J. B. Chauhan, K. M. Singh, & K. J. Soni. 2007. Allelic frequency of kappa-casein and beta-lactoglobulin in Indian crossbred (*Bos taurus* x *Bos indicus*) dairy bulls. *Turk. J. Vet. Anim. Sci.* 31: 399-402.
- Pilarczyk, R. & J. Wojcik. 2008. Comparison of body weight and reproduction performance in cows of various beef breeds managed under equal conditions in West Pomerania. *Arch. Tierz. Dummerstorf* 51: 318-328.
- Rachagani, S. & I. D. Gupta. 2008. Bovine kappa-casein gene polymorphism and its association with milk production traits. *Genet. Mol. Biol.* 31: 893-897. <http://dx.doi.org/10.1590/S1415-47572008005000001>
- Rohallah, A., M. A. Mohammadreza, & M. B. Shahin. 2007. Kappa-casein study in Iranian Sistani cattle breed (*Bos indicus*) using PCR-RFLP. *Pak. J. Biol. Sci.* 10: 4291-4294. <http://dx.doi.org/10.3923/pjbs.2007.4291.4294>
- Sitkowska, B., W. Neja, & W. Wisniewska. 2008. Relations between kappa-casein polymorphism (CSN3) and Milk Performance traits in heifer cows. *J. Central European Agriculture* 9: 641-644.
- Strzalkowska, N. J., L. Krzyzewski, Z. Zwierzchowski, & Z. Ryniewicz. 2002. Effects of K-casein and β -lactoglobulin loci polymorphism, cow's age, stage of lactation and somatic cell count on daily milk yield and milk composition in Polish Black-and-White cattle. *Anim. Sci. Papers Reports* 20: 21-35.
- Toorchi, M., A. Tahvildarzadeh, J. Shoja, & S. Alijani. 2006. Molecular characterization of CSN3 alleles in Sarabi and Holstein using PCR-RFLP. *Biotechnology* 5: 495-500.
- Tsiaras, A. M., G. G. Bargouli, G. Banos, & C. M. Boscos. 2005. Effect of kappa-casein and beta-lactoglobulin loci on milk production traits and reproductive performance of Holstein cows. *J. Dairy Sci.* 88: 327-334. [http://dx.doi.org/10.3168/jds.S0022-0302\(05\)72692-8](http://dx.doi.org/10.3168/jds.S0022-0302(05)72692-8)
- Vasconcellos, L. P. M. K., D. Tambasco-Talhari, A. P. Pereira, L. L. Coutinho, & L. C. A. Regitano. 2003. Genetic characterization of Aberdeen Angus cattle using molecular markers. *Genet. Mol. Biol.* 26: 133-137. <http://dx.doi.org/10.1590/S1415-47572003000200005>